Mechanical Effect Analysis of Braking in Sports

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Abstract: In games, high-speed movements are required to stop or slow down. It is necessary to focus on applying body force to braking. In the work, braking to change sports state was conducted with mechanical analysis to derive the key force of braking—friction force based on Newton laws of motion. After that, mechanical factors of braking were analyzed according to theorems of momentum and kinetic energy. We obtain the relation between braking effect and factors including braking force, distance and time. After impact analysis of braking action and power source, mechanical principles were applied to achieve a better braking effect by examples.

1 INTRODUCTION

In sports, human body was usually at a high-speed state. Human body was required to slow down or stop in games including dash, gymnastics, skiing, skating, football, basketball, etc. An unsuccessful braking resulted in failure and accident of sports. Therefore, mechanical effect analysis played an important role in completing sports and obtaining better competition results. Games were conducted with mechanical effect analysis based on physical principle of nature.

2 MECHANICAL PRINCIPLE ANALYSIS OF BRAKING IN SPORTS

2.1 Relation between Body Motion State and Applied Force

There are two motion states of body including stationary and uniform motion according to Newton's first law of motion—law of inertia. Body motion can be described as the result of exogenic action.

Newton's first law of motion can be expressed as follows.

$$\sum_i \vec{F}_i = 0 \Rightarrow \frac{dv}{dt} = 0$$

where $\sum_i \vec{F}_i$ is the resultant force; v the speed; t the time.

If there is no external force (Fi = 0), then the body will be static (v = 0). The Equation Fi = 0 can be divided into two conditions including bodies with a friction force of 0 and with no friction force. The forces are applied to the body to derive phenomenon of stationary-to-motion and motion-to-stationary. There are kinds of forces applied to the body, such as traction, resistance, gravity and support force. Motion state of the body is affected by resultant. If certain force is dominant, it will cause the motion result of the body. E.g., if a car is started and given enough oil, the traction will be larger than resistance. The resultant is more than 0, and the car is in a steady state. If the oil is not enough, the traction will be equal to resistance. The resultant is 0, and the car keeps moving in a steady state. If the brake is hit, the traction will be smaller than resistance. The resultant is less than 0, and the car is in a decelerated motion. In sports, we focus on mechanical effects of braking including the body with a larger traction, zero resultant and decelerated motion.

2.2 Relation between Applied Force and Accelerated Speed in a Motion State

The accelerated speed increases with the increase of the applied force based on Newton's second law of

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motion. For equivalent force, the body with smaller mass has a larger accelerated speed. The body with a mass to certain extent has no accelerated speed. The directions of the force and

$$a \propto \frac{F}{m}$$

where F is the applied force (N); m mass (kg); a accelerated speed (m/s^2).

Human is the body with kinds of motion states in sports. Newton's second motion law illustrates change of motion state and relation between applied forces. Therefore, for braking deceleration, the baking force is the key factor while the mass of body is determined. If the braking force is larger, the accelerated speed will be larger. The braking in high-speed motion will be efficiently achieved.

2.3 Friction Force—A Key of Achieving Braking in Sports

In the process of human body motion, traction is produced by friction of body muscle. The resistance of body motion, including wind and friction force, comes from body muscle motoricity. As the source of main braking force in sports, the motoricity can apply friction and resistance to human motion. For human body at a high speed, larger resistance and shorter time will cause a larger accelerated speed and better braking effect.

Mechanical effect of body from motion to static state is analyzed to derive braking effect in sports. Accelerated traction and braking resistance are realized by friction between body and ground. The friction is in proportion to pressure and friction coefficient. Therefore, braking force of body motion is determined by pressure, friction coefficient and reacting force.

For every action, there is an equal and opposite reaction based on Newton's third law of motion. An example shows a person sits in a chair. The pressure of body and the support force of the chair are a couple of actions. In sports, the pressure that body applies to the ground and the support force that ground applies to the body are a couple of actions. Then, the friction is produced to achieve traction and braking force of body motion.

The pressure that body applies to the ground is constant in high-speed motion. The friction is in proportion to friction coefficient. The friction coefficient has a close relation with sports shoes. Good sports shoes are designed considering mechanical performance, beauty, bearing and friction coefficient. Different characteristics of sports make friction coefficients of designed shoes different. In general, kinds of patterns and hobnails on the soles are designed to increase traction and braking force.

For braking effect of human body in sports, we focus on analyzing change laws of momentum and kinetic energy.

3 RELATION BETWEEN MECHANICAL BRAKING FACTORS IN SPORTS

3.1 Kinetic Analysis of Braking in Sports

Energy produced by object motion is called kinetic energy. Energy production is a process of dong work. E.g., people get hot and sweat because thermal energy is produced. In braking process, the braking force does work to change the object from motion to static state. The work is half of the product of mass and the square of speed. While the speed is the same, the cars with different masses have different kinetic energies. A truck has a larger braking distance than a car with the same speed. For the same car, the kinetic energy at high speed is larger than that at low speed. Therefore, people are required to drive slowly for safety. The result of synthetic action to an object is expressed as follows.

$$W = \frac{1}{2}mv_t^2 - \frac{1}{2}mv_0^2$$

Kinetic principle reflects cumulative effect of force in space. It can be expressed as follows.

$$Fs = \frac{1}{2}mv_t^2 - \frac{1}{2}mv_0^2$$

The mass of human body is constant in the movement. Therefore, the change of kinetic energy is determined by the speed of movement. While speed and kinetic energy are the same, braking force is inversely proportional to braking distance, and proportional to the square of speed. Consequently, the influence of speed to braking force is larger than braking distance.

3.2 Momentum Analysis of Braking in Sports

Motion effect can be reflected by momentum — product of object mass and speed. Momentum effect,

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determined by object mass and speed, can be expressed as Ft=mΔv. In time axis, momentum law is used to express accumulation of force results. So we obtain that momentum is in proportion to mass and speed.

Law of conservation of momentum is expressed as follows.

$$Ft = mv_2 - mv_1$$

In sports, human body follows law of conservation of momentum. As the mass of human body is definite, the momentum of human body is determined by the speed. The human motion braking process is a sharp change of speed. The braking momentum is in proportional to braking force and time. While braking force is constant, the change of braking momentum is proportional to braking time. When the change of momentum is constant, the braking force is reversely proportional to braking time. Therefore, braking effect can be improved by increasing braking force and time.

4 MECHANICAL ANALYSIS OF BRAKING ACTION IN SPORTS

In sports, braking action has great influence on braking force. The addition of pressure contributes to the form of larger braking force in short time. E.g., athletes raise commencing height and jump distance by high-speed approach in long jump. The athletes realize safe landing by forward stroke of legs and feet, thus avoiding falling to the ground. Mechanical analysis of this braking action is conducted. The forces applied to athletes in a jumping state are gravity and wind resistance. In long jump, the athletes form a parabolic curve of high-speed. The athlete has an inertial force forward to form momentum and kinetic energy of human body. Meanwhile, there exists downward gravity acceleration and kinetic energy. At the moment of landing, legs and feet produce ground support by forward stroke. The inertia of athletes makes a huge friction between legs and ground. The friction force is proportional to pressure while friction coefficients and areas are the same. The huge friction force will result in sudden stop of athletes' legs. If the athlete does not stop, he will fall down by effect of inertia. The athlete can increase braking time by forward stroke and bending of legs to avoid falling. The control of braking force and time can decrease the reacting force of ground to achieve effective braking of forward and downward action.

5 POWER SOURCE AND INFLUENCE OF BRAKING TO HUMAN BODY

Braking force comes from internal force of human body produced by muscle. Tensile force originates from muscle contraction, and support force from bone and soft tissue. In sports, braking force should be supported by bone and soft tissue. Overlarge braking shock will cause body hurt. E.g., in high jump, the body should fall to the buffer cushion to raise braking time. Otherwise, the huge braking counterforce will hurt human body.

6 CASE ANALYSIS USING MECHANICAL PRINCIPLES IN SPORTS

In sports, braking force is added to achieve prompt braking in a short distance. E.g., some students go climbing. A girl trips down the hill. Suddenly, a boy calls her to stop because there is a cliff ahead. The smart girl slows down with her hip on the ground. At last, she is lucky to stop. Now we analyze braking mechanical effect of the girl. The forces applied to the girl are gravity, ground supporting force, forward traction and braking friction. The angle between gravity and ground supporting force is less than 180 degree in the slope. The combined action of the two forces produces a propulsive force downward along the slope. The traction derived from gravity is added with the propulsive force to produce accelerated speed. The accelerated speed makes it difficult to stop in a finite distance. The girl applies resistance by feet while stopping traction. The friction resistance applied by her muscle is partially offset by propulsive force downward. The small friction resistance cannot achieve complete braking within finite distance. Then she sits on her hip to increase the friction force between body and ground. The friction force is proportional to the area while friction coefficients and pressures are the same. Therefore, the friction force is larger than propulsive force downward, thus achieving braking in finite distance. Finally, she stops before falling down the cliff.

7 CONCLUSIONS

Consequently, the braking effect in sports can be

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improved by addition of braking force, time and distance based on scientific theories. In daily exercises, braking effect can be improved by raising physical quality, muscular contractility and shock resistance. Besides, we can apply other methods including increasing friction coefficient of sports shoes and buffered devices. Multiple braking methods should be trained to avoid impact damage of promote braking to human body.

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